Echocardiographic Evaluation of Mitral Valve Prostheses

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GUIDELINES AND STANDARDS

Recommendations for Evaluation of Prosthetic Valves With Echocardiography and Doppler Ultrasound

A Report From the American Society of Echocardiography's Guidelines and Standards Committee and the Task Force on Prosthetic Valves, Developed in Conjunction With the American College of Cardiology Cardiovascular Imaging Committee, Cardiac Imaging Committee of the American Heart Association, the European Association of Echocardiography, a registered branch of the European Society of Cardiology, the Japanese Society of Echocardiography and the Canadian Society of Echocardiography, Endorsed by the American College of Cardiology Foundation, American Heart Association, European Association of Echocardiography, a registered branch of the European Society of Cardiology, the Japanese Society of Echocardiography, and Canadian Society of Echocardiography

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2014 AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease

A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines

Developed in Collaboration With the American Association for Thoracic Surgery, American Society of Echocardiography, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Anesthesiologists, and Society of Thoracic Surgeons

Nishimura RA et al. Circulation 2014;129:e521-e643.

Overview

- Description of the various types of prosthetic heart valves
- Echocardiographic evaluation of normally-functioning prosthetic heart valves
- Evaluation of prosthetic heart valve dysfunction

Prosthetic Heart Valves

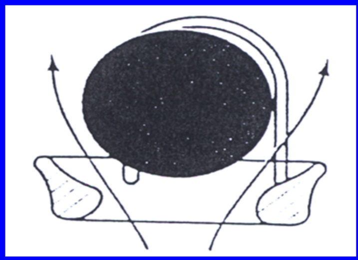
- Mechanical valves
- Tissue (biological) valves
  - Human
    - Allografts
    - Autografts
  - Animal (xenografts)
    - Porcine aortic valves
    - Bovine pericardial tissue
    - Stented or stentless
- Percutaneous valves/clips
- Annular rings

Mechanical Heart Valves

- Ball-in-cage
  - Starr Edwards valve
- Single tilting disc
  - Medtronic Hall valve
  - OmniScience valve
  - Bjork-Shiley valve
- Bileaflet tilting disc
  - St. Jude Medical valve
  - Carbomedics valve/Sorin
  - On-X
  - ATS

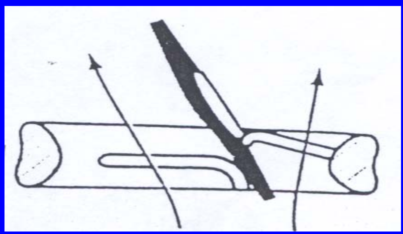
Ball-in Cage
Starr Edwards Valve

- Durable
- Structure:
  - Circular sewing ring
  - Silastic ball
  - Cage with arches
- High profile
- Flow occurs around the ball
- Higher peak velocities
- Backflow volume of 2-5 mL



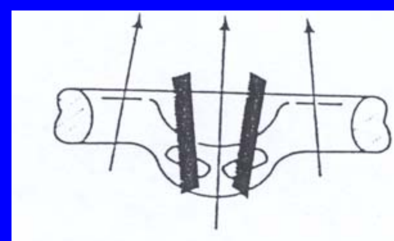
Single Tilting Disc Valves

- Structure:
  - Circular sewing ring
  - Circular disc eccentrically attached by metal struts
- Closing angle 110º to 130º
- Opening angle 60º to 80º
- Flow occurs through major and minor orifices
- Backflow volume of 5-9 mL



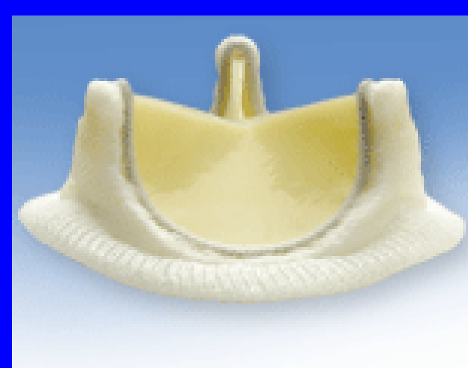
Bileaflet Tilting Disc Valves

- Structure:
  - 2 semicircular discs attached to rigid valve ring by small hinges
- Closing angle 120° to 130°
- Opening angle 75° to 90°
- 3 orifices
  - Central and 2 lateral orifices
- Backflow volume of 5-10 mL



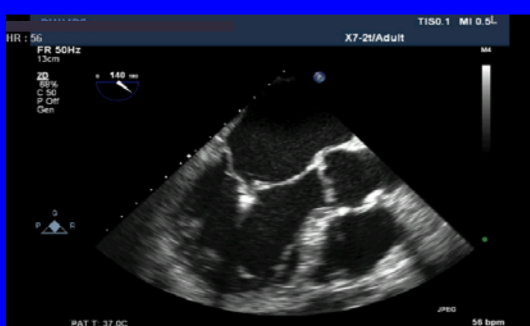
Stented Heterograft Valves

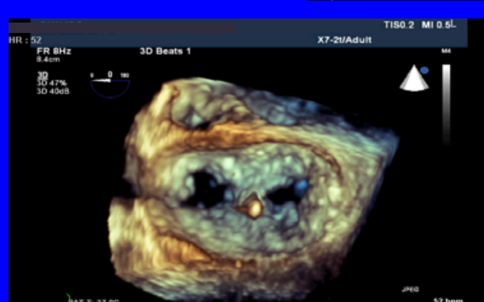
- Structure:
  - Sewing ring with 3 semi-rigid stents or struts and fabric sewing cuff
    - Porcine aortic tissue
    - Bovine pericardium
- Trileaflet
  - Opens to a circular orifice
- Regurgitant volume
  - About 1 mL
  - 10% exhibit a small degree of regurgitation on color flow imaging



Percutaneous Clip

- Mitra-Clip®
- Perctaneous edge-to-edge technique to reduce MR
- Currently FDA-approved for degenerative MR





Echocardiographic Approach to Assessment of Prosthetic Heart Valves

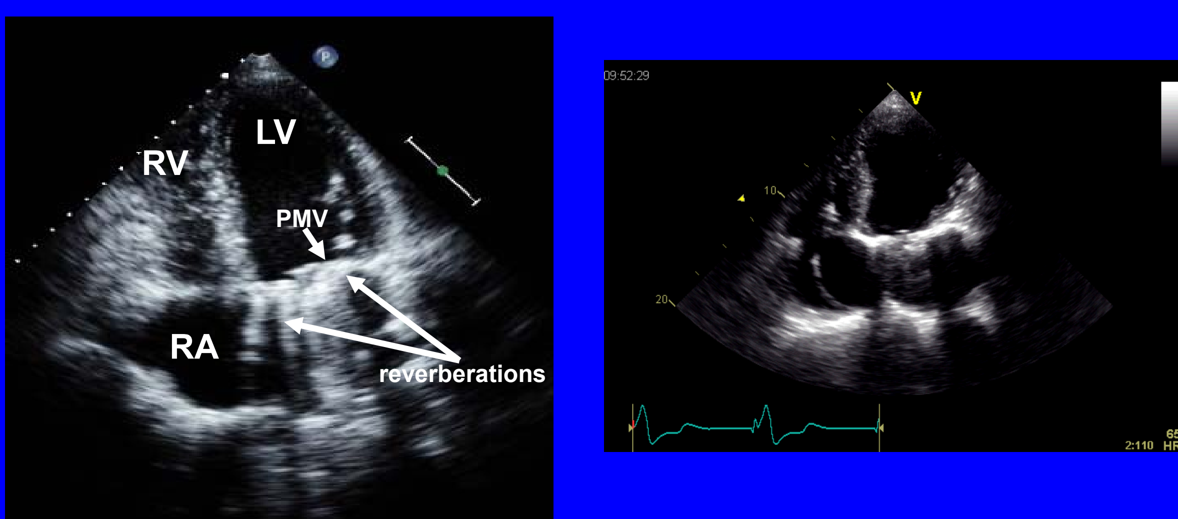
- Evaluation similar to that of native valves
- Reverberations and shadowing play a significant role
- Fluid dynamics of each specific valve prosthesis influences the Doppler findings

Echocardiographic Approach to Prosthetic Heart Valves—All Valve Types

- Complete 2D/3D imaging
- Determine trans-valvular pressure gradients
- Estimate valve orifice area
- Evaluate severity and location of regurgitation
- Estimate pulmonary artery systolic pressure
- Assess chamber sizes and function
- Evaluate other valves
- Clinical data
  - Size and type of prosthesis
  - Date of implant
  - HR, BP, BSA
- ***ALWAYS COMPARE TO BASELINE STUDY!***

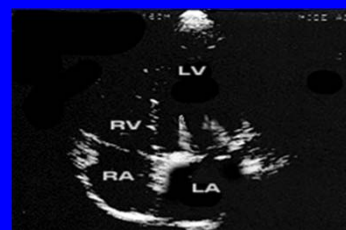
Echocardiographic Approach to Prosthetic Heart Valves—Caveats

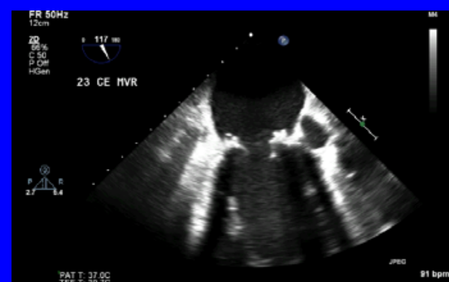
- "Normal" Doppler values based on:
  - Prosthesis size
  - Prosthesis type
- Higher gradients expected compared to native valves
- Effect of reverberation artifacts/shadowing
- Differential diagnosis of high valve gradients:
  - True stenosis
  - High cardiac output states
  - Significant regurgitation
  - Patient-prosthesis mismatch
  - Pressure recovery

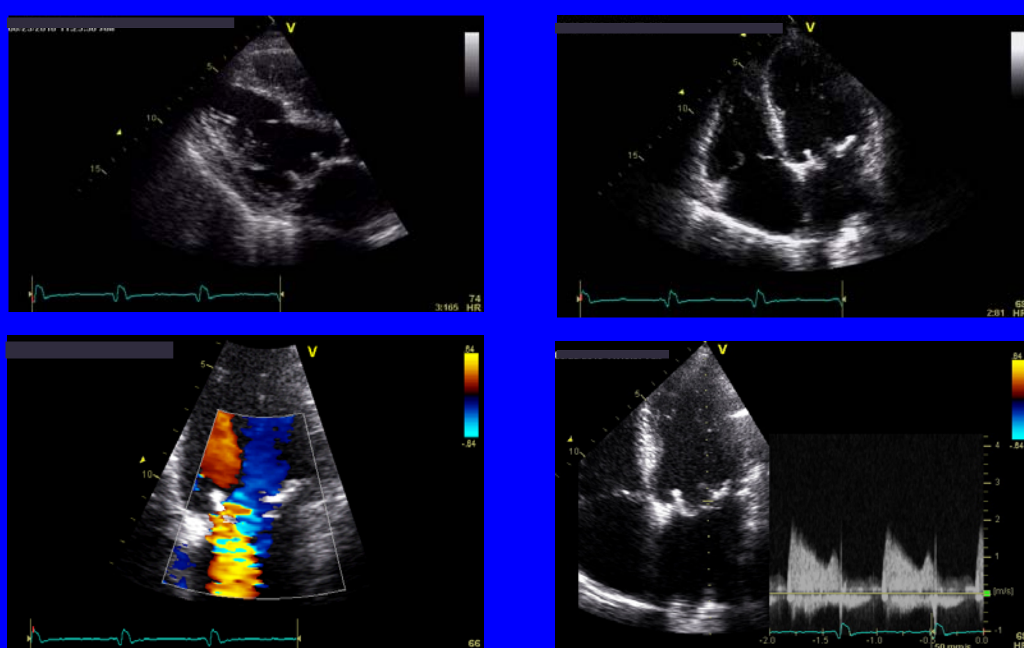


Normal Appearance: Tissue Valves

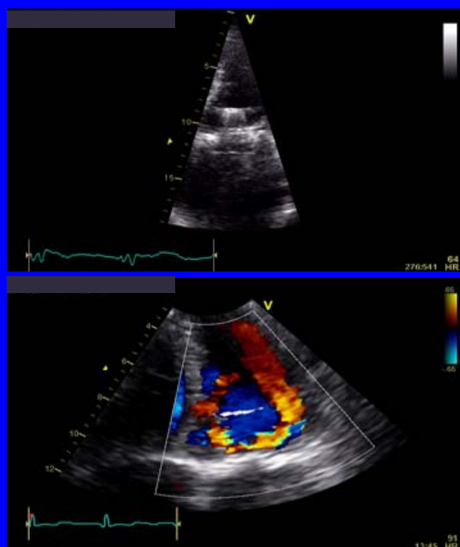
- Stented valves
  - 3 cusps and struts
  - Echogenic sewing ring







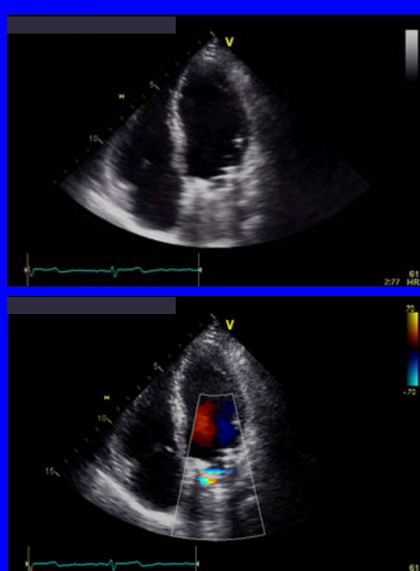
Normal Appearance: Mechanical Valves

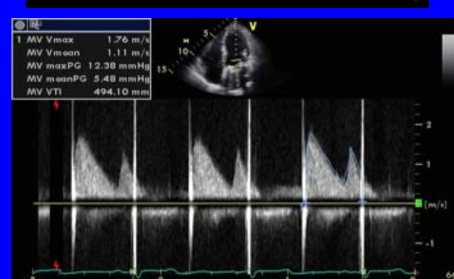


Ball in cage

Single tilting disk

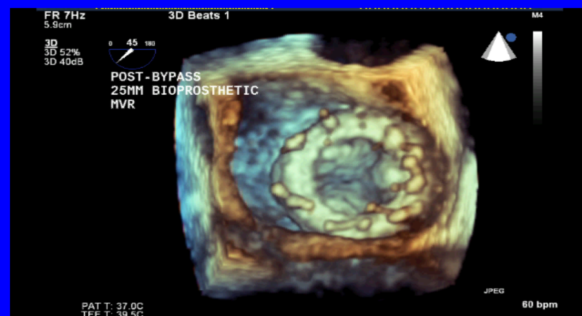
Bileaflet Mechanical Prosthesis





3-D Appearance

Bileaflet Mechanical Prosthesis



Bioprosthesis

Complications of Prosthetic Valves

- **Early**
  - Paravalvular leaks
  - Thrombosis/stuck occluders
  - Low output state
  - LVOT obstruction
  - Infective endocarditis
  - Patient prosthesis mismatch (PPM)
- **Late**
  - Structural valve deterioration
  - Thrombosis/thromboembolism
  - Bleeding
  - Pannus ingrowth
  - Paravalvular regurgitation
  - Infective endocarditis
  - Patient prosthesis mismatch
  - Hemolysis
  - Pseudoaneurysm formation

15-year Event Rates

	Mitral Valve Replacement		
	Mechanical	Bioprosthesis	p Value
	n = 88	n = 93	
Death from any cause	81 ± 4%	79 ± 4%	0.30
Any valve-related complication	73 ± 6%	81 ± 5%	0.56
Systemic embolism	18 ± 5%	22 ± 5%	0.96
Bleeding	53 ± 7%	31 ± 6%	0.01
Endocarditis	11 ± 4%	17 ± 5%	0.37
Valve thrombosis	1 ± 1%	1 ± 1%	0.95
Perivalvular regurgitation	17 ± 5%	7 ± 4%	0.05
Reoperation	25 ± 6%	50 ± 8%	0.15
Primary valve failure **(SVD)**	5 ± 4%	44 ± 8%	0.0002

Hammermeister K et al. J Am Coll Cardiol 2000;36:1152.

Outcomes of MVR in Patients 50 to 69 years

	No. (%) [95% CI] by Type of Mitral Valve Replacement		
Outcome at 15 Years	Mechanical Prosthetic (n = 664)	Bioprosthetic (n = 664)	Hazard Ratio (95% CI)
Death	209	221	
Actuarial 15-year survival, % (95% CI)	57.5 (50.5-64.4)	59.9 (54.8-65.0)	0.95 (0.79-1.15)
Stroke	65 (14.0) [9.5-18.6]	41 (6.8) [4.5-8.8]	1.62 (1.10-2.39)
Reoperation	28 (5.0) [3.1-6.9]	47 (11.1) [7.6-14.6]	0.59 (0.37-0.94)
Bleeding events	72 (14.9) [11.0-18.7]	49 (9.0) [6.4-11.5]	1.50 (1.05-2.16)

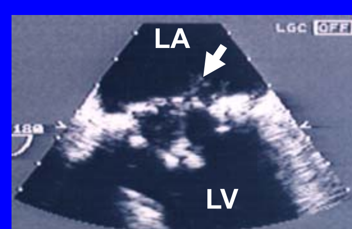
Chikwe J et al. JAMA 2015;331:1435-1442.

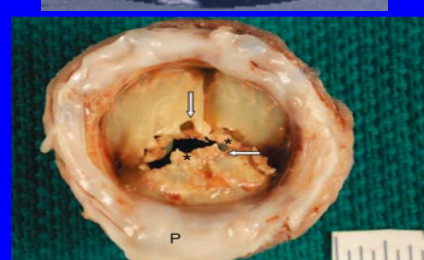
Prosthetic Valve Dysfunction

- Approach to suspected dysfunction
  - Echocardiography
    - TTE/Doppler
    - TEE
      - Atrial side of mitral prosthesis
  - Cine fluoroscopy
    - Assessment of mechanical valve opening and closing motion
    - No assessment of pressure gradients
  - Cardiac CT
  - PET/CT
  - Stress echocardiography
  - Cardiac catheterization

Structural Valve Deterioration

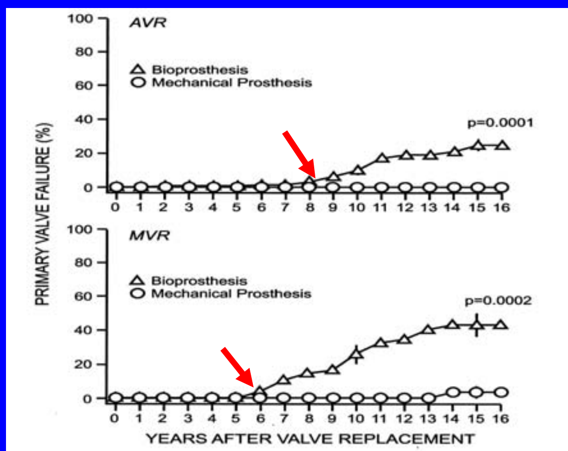
- Tissue Valves
  - More common
    - Younger patients
    - Altered Ca^{++} metabolism
    - Valve type
  - Thickening, calcification, perforation, or spontaneous tissue degeneration of leaflets
  - Regurgitation
    - Usually gradual
    - Can be acute and massive
  - Stenosis
  - Combination



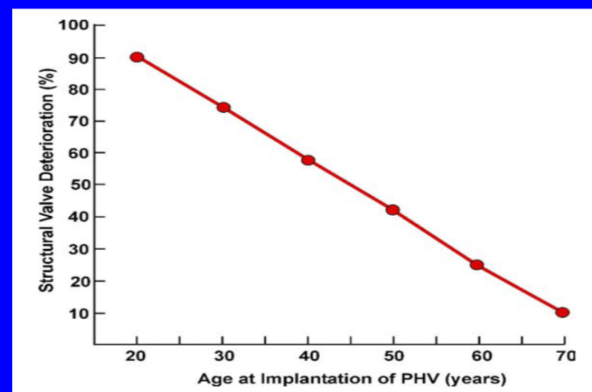


Siddiqui RF et al. Histopathology 2009;55:135.

Structural Valve Deterioration



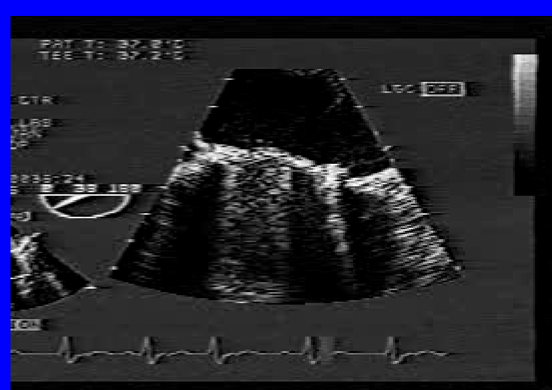
Hammermeister K et al. J Am Coll Cardiol 2000;36:1152.



Rahimtoola SH. J Am Coll Cardiol 2010;55:2413.

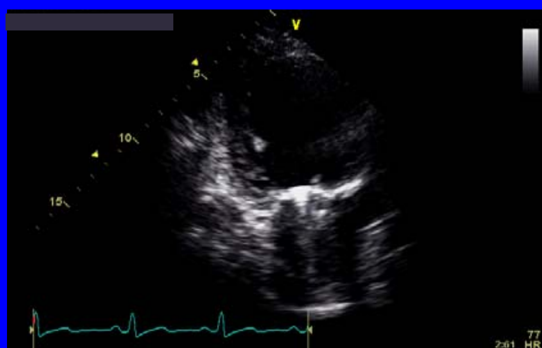
Valve Thrombosis/Thromboembolism

- Incidence
  - 0.3% to 1.3%/yr
- Highest risk
  - Mitral and tricuspid positions
  - Inadequate anticoagulation
- BPVT increasing recognition
- Clinical manifestations
  - Incidental finding
  - Peripheral embolization
  - Stenosis
  - Regurgitation
  - Heart failure/shock
- Symptom onset
  - Gradual or acute
- Treatments
  - Anticoagulation
  - Thrombolysis
  - Surgery

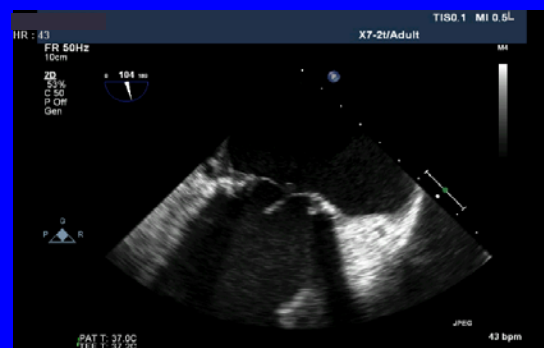


Bileaflet MVR

Non-obstructive Thrombosis



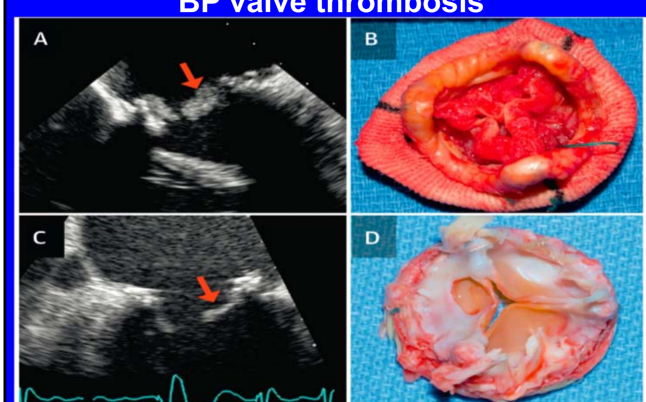
Mechanical Prosthesis



Bioprosthesis

BPVT vs. Structural Valve Deterioration

BP valve thrombosis



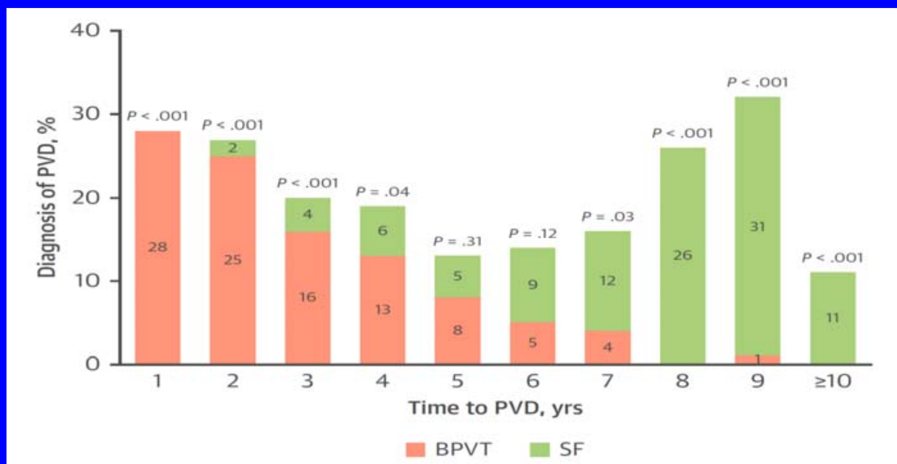
Structural valve deterioration

TABLE 5 Test Performance Characteristics for the Diagnosis of BPVT

	Total Score	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Variables					
A. 50% mean gradient increase	1	45	89	68	77
B. Increase cusp thickness	1	74	69	55	84
C. Abnormal cusp mobility	1	63	70	51	81
D. Paroxysmal AF	1	63	73	54	80
E. Subtherapeutic INR	1	30	92	67	73
Combination of variables					
A and B	2	86	57	50	89
A, B, and C	3	72	90	78	87
A, B, C, and D	4	70	94	87	86
A, B, C, D, and E	5	66	93	85	89

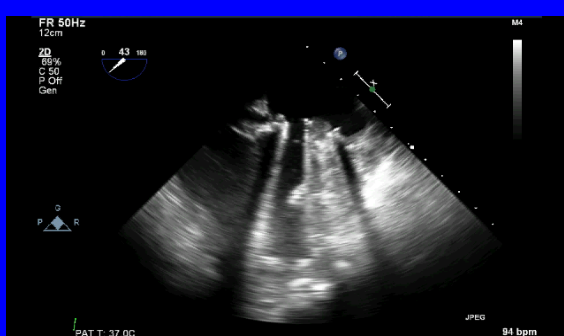
Egbe AC et al. J Am Coll Cardiol 2015;66:2285.

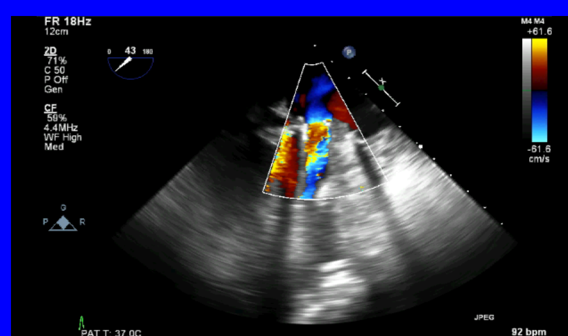
Annual Occurrence of Bioprosthetic Valve Dysfunction



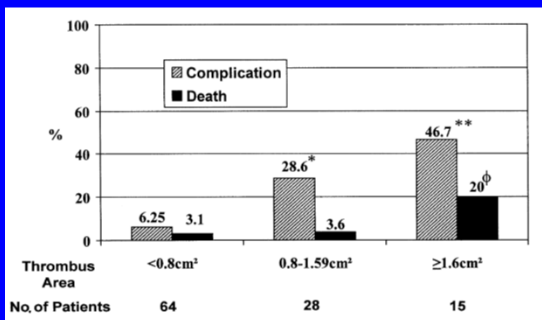
Egbe A et al. JACC Cardiovasc Imaging 2017.

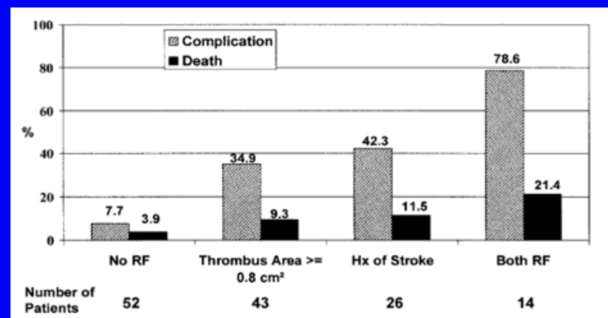
Obstructive Thrombosis



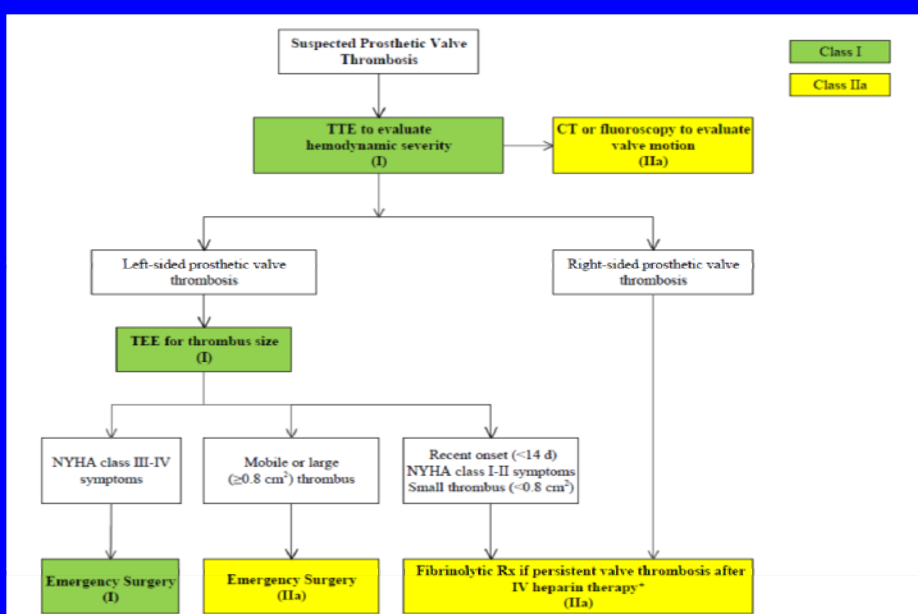


Thrombus Area by TEE Predicts Clinical Outcome





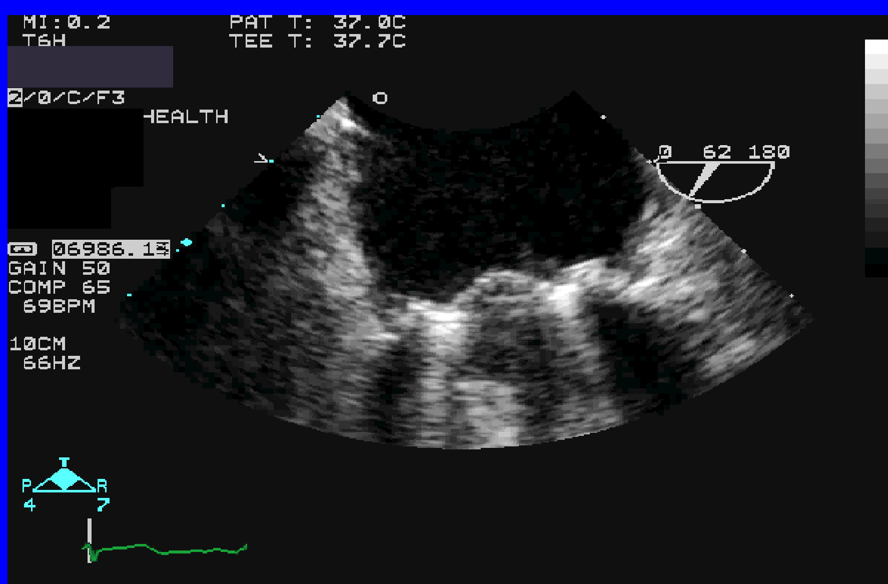
Tong AT et al. J Am Coll Cardiol 2004;43:77.

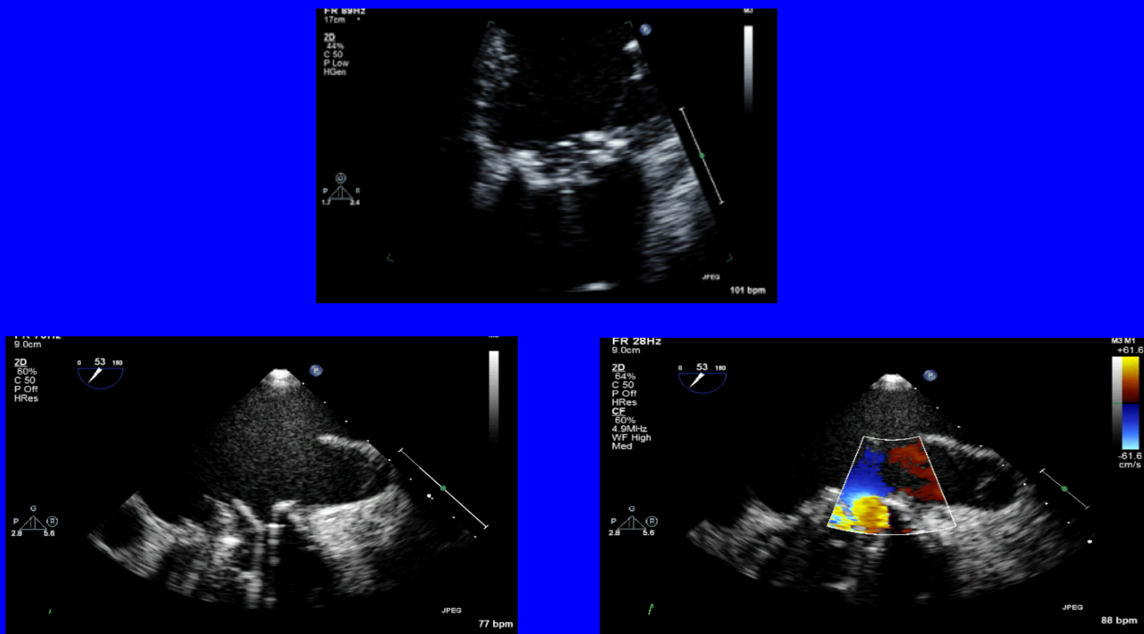


Nishimura RA et al. Circulation 2014 ;129:e586.

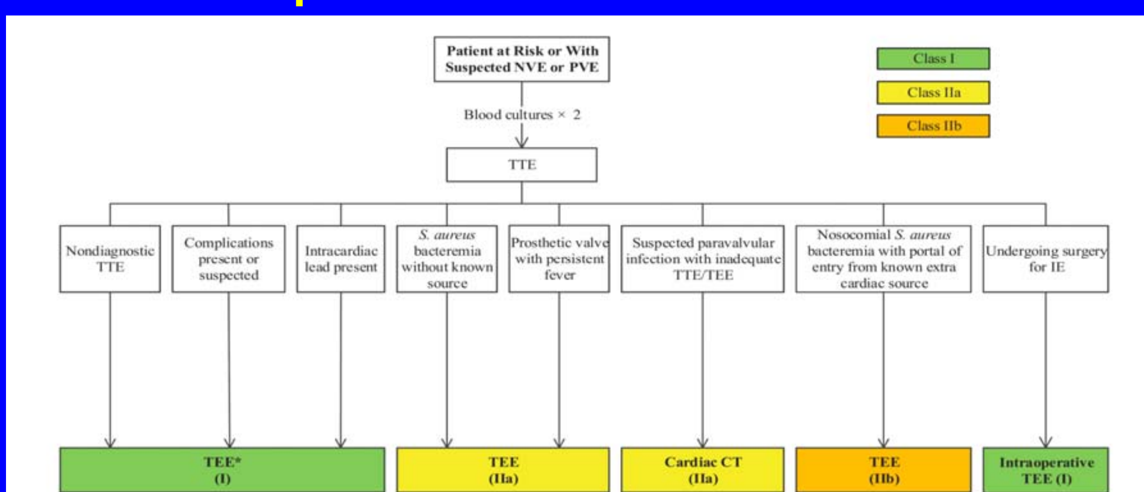
Infective Endocarditis

- Risk approximately 0.5%/year
- Early versus late pathogens
- Mechanical valves
  - Usually involves the sewing ring
  - Rare to visualize vegetation on discs
- Tissue valves
  - Vegetations seen at sewing ring and/or leaflets
- Complications
  - Heart failure
  - Abscess/fistula formation
  - Regurgitation: paravalvular or valvular
  - Stenosis
  - Embolism
  - Conduction defects





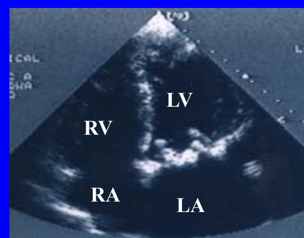
Imaging Evaluation for Suspected Infective Endocarditis

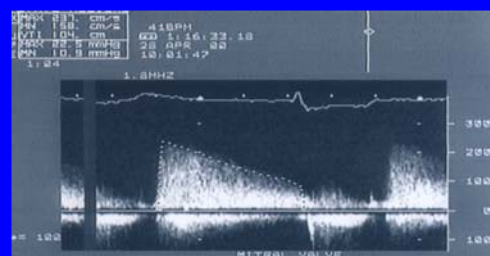


Nishimura RA et al. Circulation 2014;129:e590.

Valve Stenosis/Obstruction

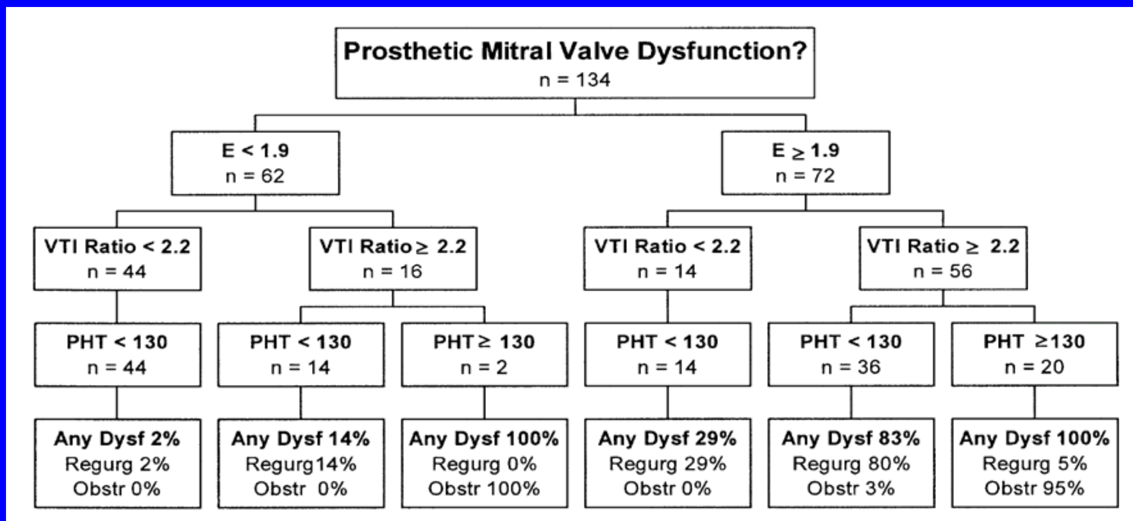
- Tissue valves
  - Thickening, calcification and restricted motion
  - Pannus in-growth
  - Thrombosis
- Mechanical valves
  - Restriction of disc/ball motion
    - Thrombus
    - Pannus in-growth
    - Combination
    - Vegetations
  - Restriction of annular area
    - Pannus in-growth



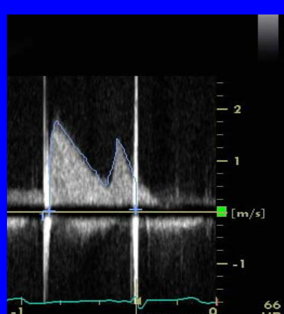


Valve Stenosis/Obstruction

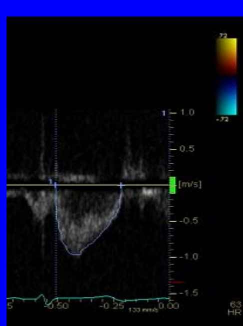
- Mitral valve parameters:
  - Peak E-wave velocity
  - Mean gradient
  - Pressure half-time
  - Effective orifice area
    - Continuity equation area
  - DVI
    - $VTI_{prosthesis}$/ VTI_{LVOT}



Fernandes V et al. Am J Cardiol 2002;89:704.

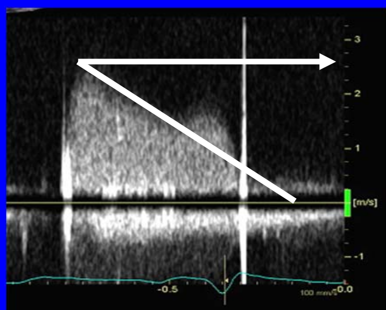


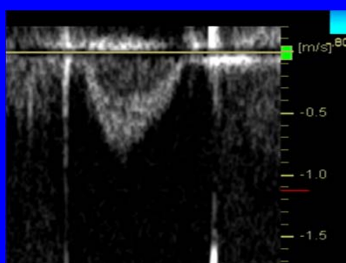
Peak E-wave	**1.76 m/sec**
PHT	**120 msec**
VTI_{pros}	**45 cm**



VTI_{lvot}	**22 cm**

DVI = 2.04

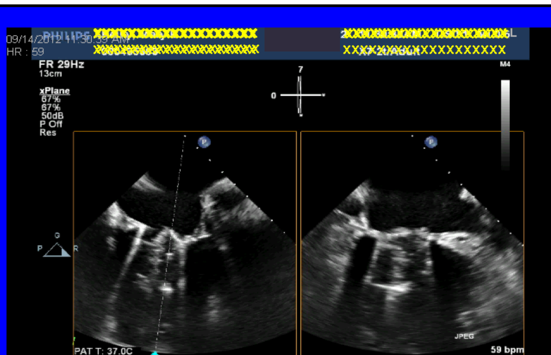


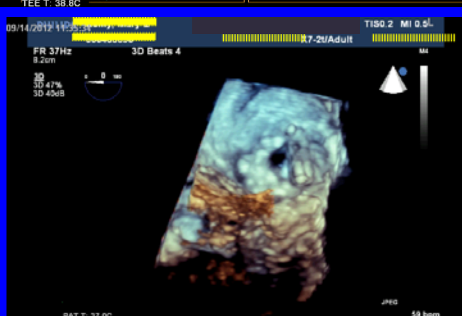


Peak E-wave	**2.6 m/sec**
PHT	**166 msec**
VTI_{pros}	**99 cm**

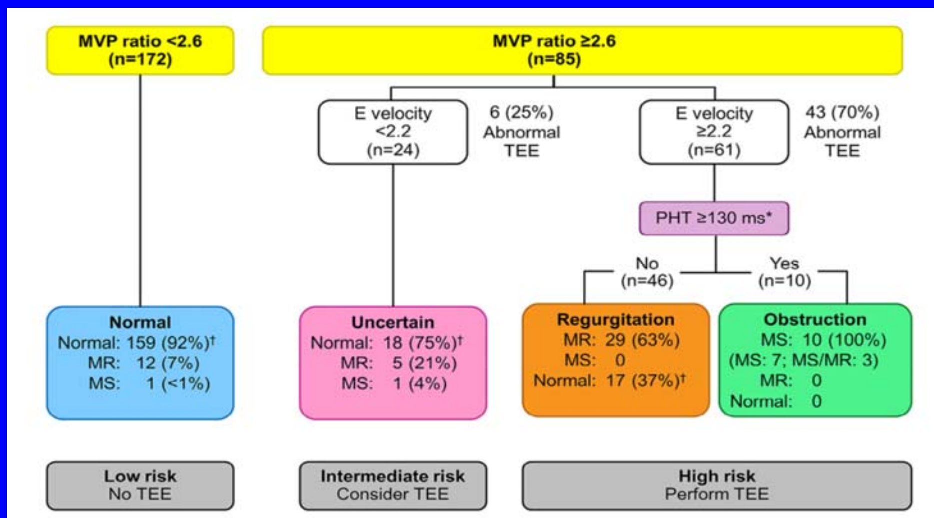
VTI_{LVOT} 17 cm

DVI = 5.8



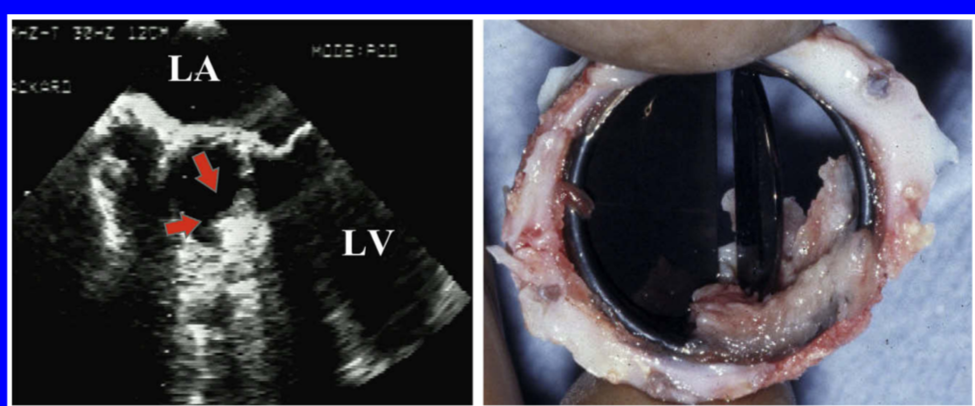


An Algorithm for Evaluation of Bioprostheses



Luis SA et al. Am J Cardiol 2017;120:1373.

Pannus In-growth



Versus Thrombosis

- Anticoagulation usually adequate
- Greater time from implant to presentation
- More echo-dense
- Aortic position more common

Zoghbi WA et al. J Am Soc Echocardiogr 2009;22:975.

Valve Stenosis/Obstruction

- Differential Diagnosis
  - High cardiac output states
    - Anemia, fever, hypovolemia, thyrotoxicosis
  - Significant regurgitation
  - Patient-prosthesis mismatch
  - Pressure recovery
- Caveats
  - Compare to baseline study
  - Take into account:
    - Size/type of prosthesis
    - Cardiac output
    - Heart rate
  - Be aware of pressure recovery
    - Bileaflet mechanical valves primarily in aortic position

Valve Stenosis/Obstruction

Table 8 Doppler parameters of prosthetic mitral valve function

	Normal*	Possible stenosis‡	Suggests significant stenosis* ‡
Peak velocity (m/s)† §	<1.9	1.9-2.5	≥2.5
Mean gradient (mm Hg)† §	≤5	6-10	>10
VTI_{PrMV}/VTI_{LVO} † §	<2.2	2.2-2.5	>2.5
EOA (cm^2)	≥2.0	1-2	<1
PHT (ms)	<130	130-200	>200

Zoghbi WA et al. J Am Soc Echocardiogr 2009;22:975.

Note: PHT is not a valid measure of EOA

Prosthetic Regurgitation

- Tissue valves
  - Degenerative/calcific changes
  - Infective endocarditis
  - Pannus in-growth
  - Paravalvular
- Mechanical valves
  - Paravalvular
    - Dehiscence
    - Poor seating
    - Infection
  - Incomplete closure
    - Pannus in-growth
    - Thrombosis

Prosthetic Regurgitation

Differentiating "Normal" from Pathological Regurgitation

Normal

- Characteristic pattern for each valve type
- Symmetric
- Brief
- Non-turbulent
- Lack of associated features
  - Increased antegrade velocities
  - Effects on chamber size and function (hyperdynamic)
  - Increased PASP

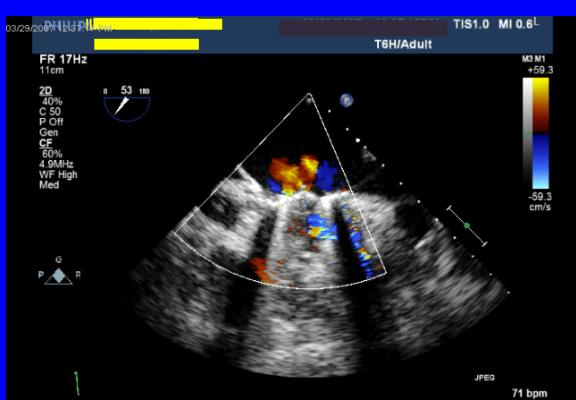
Pathological

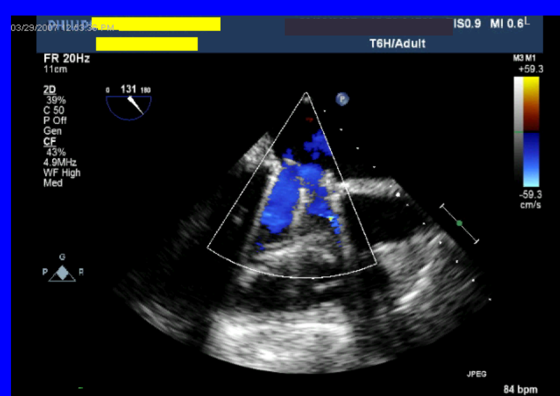
- Asymmetric
  - May flow along atrial wall
- Greater flow duration
  - Persists well into systole
- Turbulent (mosaic) pattern
- Proximal flow acceleration may be present
- Presence of associated features

Evaluation of Prosthetic Regurgitation

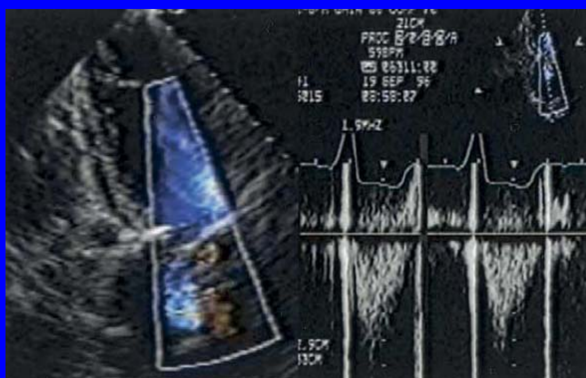
- Similar to native valve evaluation
- Prosthetic shadowing limits evaluation
  - Mitral: TEE superior to evaluate LA aspect
- “Pseudo-regurgitation”

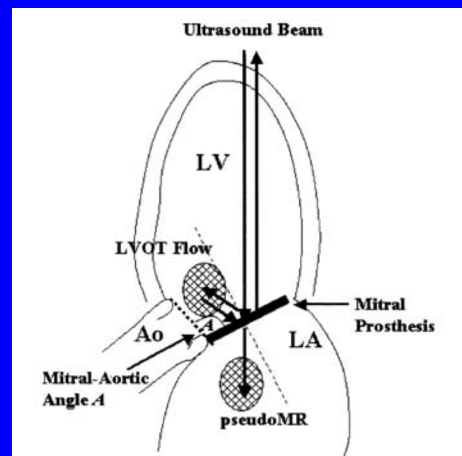
Bileaflet Mechanical Prosthesis
Normal Color Flow Pattern





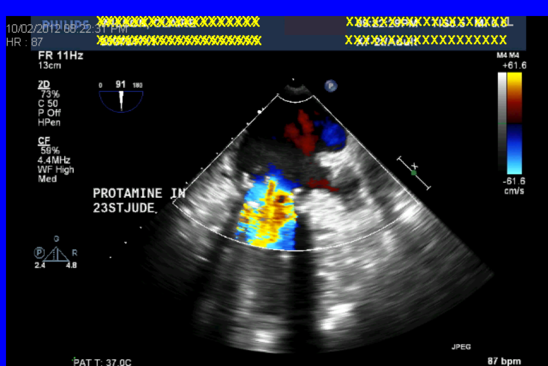
Pseudo-regurgitation

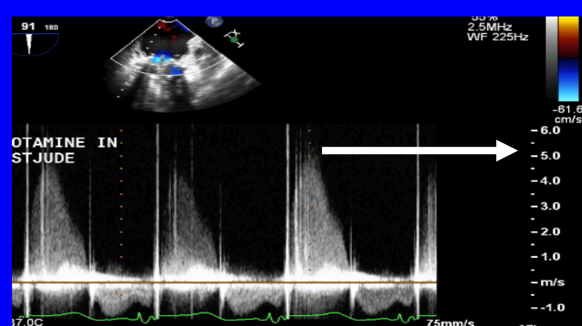


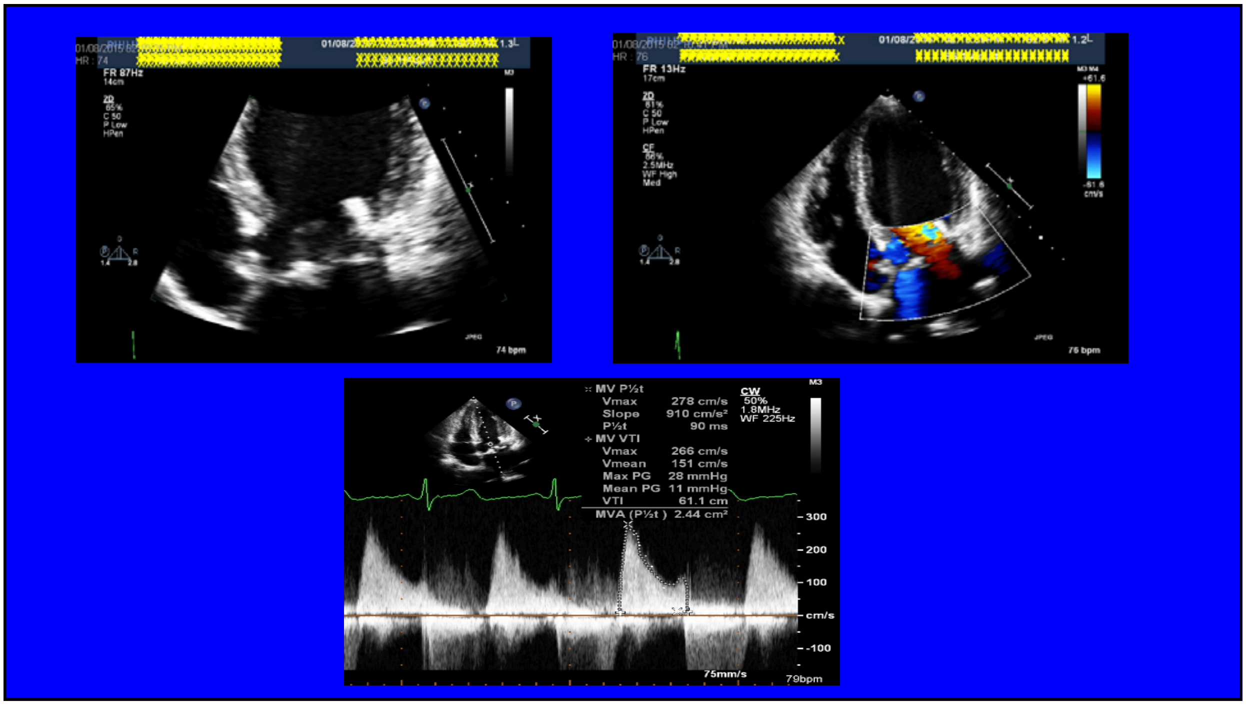


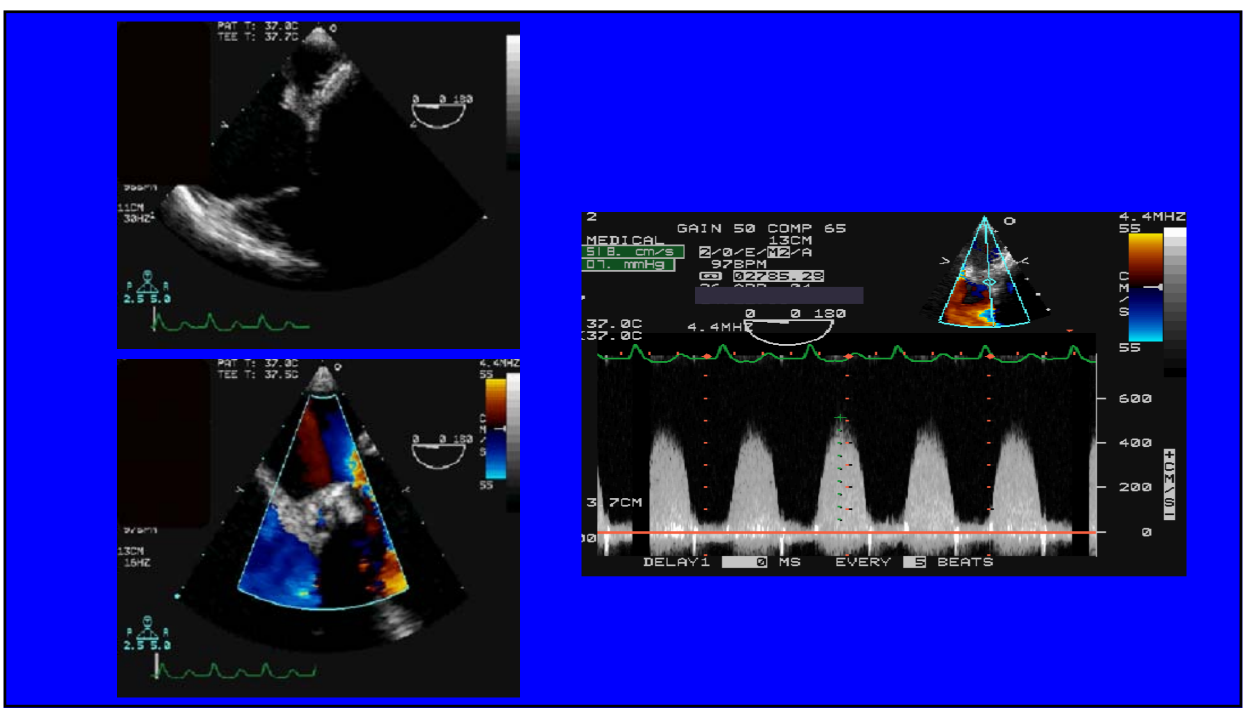
Rudski LG et al. J Am Soc Echocardiogr 2004;17:829.

Immediate Post-operative Paravalvular MR






FR 87Hz
FR 13Hz
74 bpm
76 bpm
MV P½t
Vmax 278 cm/s
Slope 910 cm/s²
P½t 90 ms
MV VTI
Vmax 266 cm/s
Vmean 151 cm/s
Max PG 28 mmHg
Mean PG 11 mmHg
VTI 61.1 cm
MVA (P½t) 2.44 cm²
CW
50%
1.8MHz
WF 225Hz
300
200
100
cm/s
-100
75mm/s
79bpm


GAIN 50 COMP 65
13CM
97BPM
4.4MHZ
600
400
200
0
CM/S
DELAY1 0 MS EVERY 5 BEATS

TTE Findings Suggestive of Significant Prosthetic MR in Mechanical Valve with Normal PHT*

Finding	Sensitivity	Specificity	Comments
Peak mitral velocity $\geq$1.9 m/s*	90%	89%	Also consider high flow, PPM
$VTI_{PrMV}/VTI_{LVO} \geq 2.5$*	89%	91%	Measurement errors increase in atrial fibrillation due to difficulty in matching cardiac cycles; also consider PPM
Mean gradient $\geq$ 5 mmHg*	90%	70%	At physiologic heart rates; also consider high flow, PPM
Maximal TR jet velocity > 3 m/s*	80%	71%	Consider residual postoperative pulmonary hypertension or other causes
LV stroke volume derived by 2D or 3D imaging is >30% higher than systemic stroke volume by Doppler	Moderate sensitivity	Specific	Validation lacking; significant MR is suspected when LV function is normal or hyperdynamic and VTI_{LVO} is <16 cm
Systolic flow convergence seen in the left ventricle toward the prosthesis	Low sensitivity	Specific	Validation lacking; technically challenging to detect readily

***PHT <130 msec**

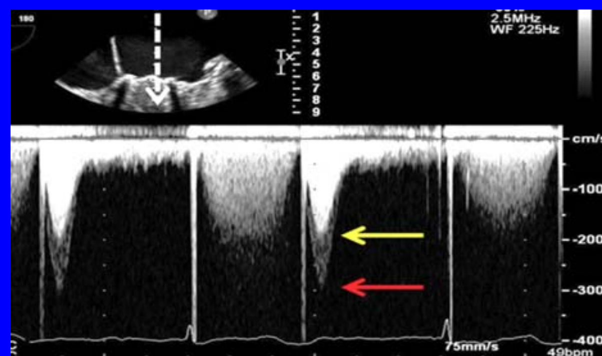
Zoghbi WA et al. J Am Soc Echocardiogr 2009;22:975.

Prosthesis-Patient Mismatch

- Effective orifice area (EOA) of the prosthetic valve is less than that of the normal native valve
  - PPM occurs when EOA is smaller than expected for BSA
- High trans-valvular gradients with normal valve function
- EOA indexed to body surface area (EOAi)
  - Mitral valve:
    - Non-significant >1.2 cm^2/m^2
    - Moderate >0.9 cm^2/m^2 to ≤1.2 cm^2/m^2
    - Severe $\leq$0.9 cm^2/m^2
- Consequences may include:
  - Exercise intolerance
  - Higher pulmonary artery pressures
  - Heart failure
  - Increased mortality

Miscellaneous Findings

Cavitary microbubbles



Double spectral profile

Hahn RT. Cardiol Clin 2013;31:287-309.

Follow-up of Prosthetic Heart Valves
ACC/AHA Guidelines

- Class I
  - Initial TTE is recommended after prosthesis implantation (6 wks to 3 mos) for assessment of valve hemodynamics (LOE: B).
  - Repeat TTE is recommended with a change in clinical symptoms or signs suggesting prosthetic valve dysfunction (LOE: C).
  - TEE is recommended when clinical symptoms or signs suggest prosthetic valve dysfunction (LOE: C).
- Class IIa
  - Annual TTE is ***reasonable*** in patients with a bioprosthetic valve after the first 10 years, even in the absence of a change in clinical status (LOE: C).

Nishimura RA et al. Circulation 2014;129:e577-e578.

Thank you for your attention